

## HYDROGEN ISOTOPES RECORD THE HISTORY OF THE MARTIAN HYDROSPHERE AND ATMOSPHERE.

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**Introduction:** The surface geology and geomorphology of Mars indicates that it was once warm enough to maintain a large body of liquid water on its surface, though such a warm environment might have been transient [e.g., 1, 2]. The transition to the present cold and dry Mars is closely linked to the history of surface water, yet the evolution of surficial water is poorly constrained. This study presents insights from hydrogen isotopes for the origin and evolution of Martian water reservoirs.

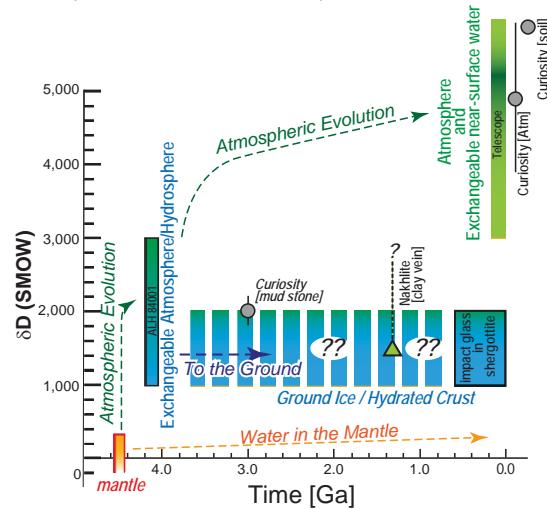
**Origin and Evolution of Water Reservoirs:** Three distinct water reservoirs are identified based on the analyses of Martian meteorites, telescopic observations, and *Curiosity* measurements (see [3], and references therein) (Fig. 1). One is mantle-derived water that has a D/H ratio similar to that seen in planetary building blocks (i.e., chondrites [4]). Assuming that Mars has not experienced significant crust-mantle recycling, the primordial water of Mars may actually have a lower value than the most primitive values observed in surface materials. Nevertheless, the most promising estimate for this primordial water reservoir ( $\delta D = <275 \text{ ‰}$ ) was obtained from olivine-hosted melt inclusions in the most magnesian olivine-phyric shergottite Yamato 980459 [5].

The second reservoir is atmospheric water with a mean D/H ratio of ~6 times the terrestrial value (Fig. 1). This is in contrast to the chondritic and Earth-like D/H ratio of primordial water retained in the Martian interior. The high atmospheric D/H ratio is interpreted to result from the preferential loss of hydrogen relative to the heavier deuterium from the top of the atmosphere throughout the planet's history. A box-model calculation based on meteorite D/H ratios suggests that the water loss due to atmospheric escape was more efficient during the pre-Noachian (>41-99 m global equivalent layer GEL) than in the rest of Martian history (>10-53 m GEL) [6]. This calculation also requires that undetected subsurface water/ice (~100-1000 m GEL) be present and that it exceeds the observable present water inventory (~20-30 m GEL) on Mars.

This third, subsurface reservoir, has been recently detected based on analyses of Martian near-surface materials [3, 7]. This reservoir has a relatively restricted range of D/H ratios ( $\delta D = \sim 1000 - 2000 \text{ ‰}$ ), which is distinct from the low-D/H primordial and the high-

D/H atmospheric water reservoirs. Since this intermediate-D/H reservoir is observed in a diverse range of Martian materials with different ages (SNC, ALH 84001, *Curiosity* surface data), this intermediate-D/H reservoir is likely a global surficial feature that has remained relatively intact over geologic time (Fig. 1).

We propose that the intermediate-D/H reservoir represents either hydrated crust and/or ground ice interbedded within sediments. The hydrated crustal materials and/or ground ice could have possibly acquired its intermediate-D/H composition from the ancient surface water before the rise of the atmospheric D/H ratio to the present level of ~5000 ‰. During ancient times, the atmosphere and hydrosphere could have approached isotopic equilibrium due to the high water activity relative to the recent dry Mars.



**Figure 1:** Hydrogen isotopic compositions of Martian water reservoirs [3, 5, 6].

- References:**
- [1], Carr M. H. and Head J. W. (2010). *EPSL*. 294, 185-203.
  - [2], Ehlmann B. L. and Edwards C. S. (2014). *Annu Rev Earth Planet Sci Lett*. 42, 291-315.
  - [3], Usui T., et al. (2015). *EPSL*. 410, 140-151.
  - [4], Alexander C. M. O. D., et al. (2012). *Science*. 337, 721-723.
  - [5], Usui T., et al. (2012). *EPSL*. 357-358, 119-129.
  - [6], Kurokawa H., et al. (2014). *EPSL*. 394, 179-185.
  - [7], Mahaffy P., et al. (2014). *Science*. 10.1126/science.1260291.